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REPORT

The U.S. Fact Sheet's Missing Parts: Iran's Near 20 Percent LEU

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Summary

Despite the fact that Iran no longer has a stock of near 20 percent low enriched uranium (LEU) in hexafluoride form (UF_6), it continues to retain a significant portion of this material in the form of oxide. In total, at the end of June, Iran will possess about 228 kilograms (kg) of near 20 percent LEU (uranium mass). Based on historical data, an estimated 43 kg will be in uranium oxide powder at the end of June. About 125 kg will be in scrap, waste, and in-process. Another 60 kg of this LEU is expected to be in Tehran Research Reactor (TRR) fuel. Most of the LEU in the TRR fuel will be fresh and not irradiated. Irradiated LEU is typically much harder to chemically process and use in a breakout than unirradiated LEU.

The U.S. Fact Sheet which outlines the parameters of a long term agreement with Iran does not discuss the fate of the near 20 percent LEU. It does discuss a cap of 300 kg of LEU in Iran but this cap refers to LEU enriched under 3.67 percent and not the near 20 percent LEU. U.S. officials have stated that the near 20 percent remaining in Iran would need to be mixed with aluminum, a step in making the fuel, or be in TRR fuel elements. Once so mixed, U.S. officials have stated that they remove this near 20 percent from consideration in breakout calculations. However, it is unclear if Iran has accepted this condition and more importantly whether this removal is justified. The U.S. condition in fact may undermine its claim that the limits on Iran's centrifuge program achieve a 12 month breakout.

The amount of Iran's near 20 percent LEU, in any form, should be reduced as much as possible to ensure that breakout periods remain at least 12 months, whether discussing overt or covert routes. The reason is simple: not only is the LEU oxide powder easily re-convertible to hexafluoride, but other forms of near 20 percent LEU can be recovered into hexafluoride form in a straightforward manner, even when in a uranium/aluminum mixture in fuel or in a production form. Once reconverted to a hexafluoride form, this LEU can be used in a breakout, significantly lowering breakout timelines because near 20 percent LEU is much closer to weapon-grade uranium than 3.5 percent LEU or natural uranium. For example, if Iran can reconvert simply 50 kilograms of near 20 percent LEU hexafluoride (about 36 kilograms uranium mass), or about 16 percent of its current stock of this material, it can reduce a 12 month breakout timeline to about eight months. A rule of thumb is that in a breakout 50 kg of near 20 percent LEU hexafluoride is worth 500 kg of 3.5 percent LEU hexafluoride.

Thus, a challenge for negotiators is to remove from Iran or blend down to natural uranium most of this LEU. The obvious target is the expected 43 kg in oxide powder and the 125 kg in the form of scrap, waste, and in-process, which total 168 kg and represent almost 75 percent of Iran's stock of near 20 percent LEU. However, this step is not enough. The LEU in fresh or unirradiated TRR fuel should also be

made less usable in a breakout. One method to do that is to irradiate all the TRR fuel, at least partially, to increase the complication of extracting the LEU from the fuel.

Any near 20 percent unirradiated LEU that remains in Iran should count against the cap of 300 kg of LEU allowed in Iran under a long-term agreement. In determining its 3.67 percent LEU equivalence, the amount of near 20 percent LEU should be appropriately weighted.

Introduction

As confirmed by the International Atomic Energy Agency (IAEA), Iran no longer has a stock of near 20 percent low enriched uranium (LEU) in hexafluoride form (see table 1). However, it retains a significant portion of this material in a different chemical form, namely oxide (see figure 1).

Iran's goal is to process the near 20 percent LEU into fuel for the Tehran Research Reactor. The processing has been inefficient, however, resulting in large amounts of LEU ending up in scrap and waste. The first step in making the fuel is converting the LEU hexafluoride into LEU oxide. During this process, which Iran has completed, only about 70 percent of the LEU ended up as oxide powder. The rest is in scrap and waste. The second step is making TRR fuel from the oxide powder. This stop has also been inefficient with typically no more than 50 percent of the LEU ending up in fuel.

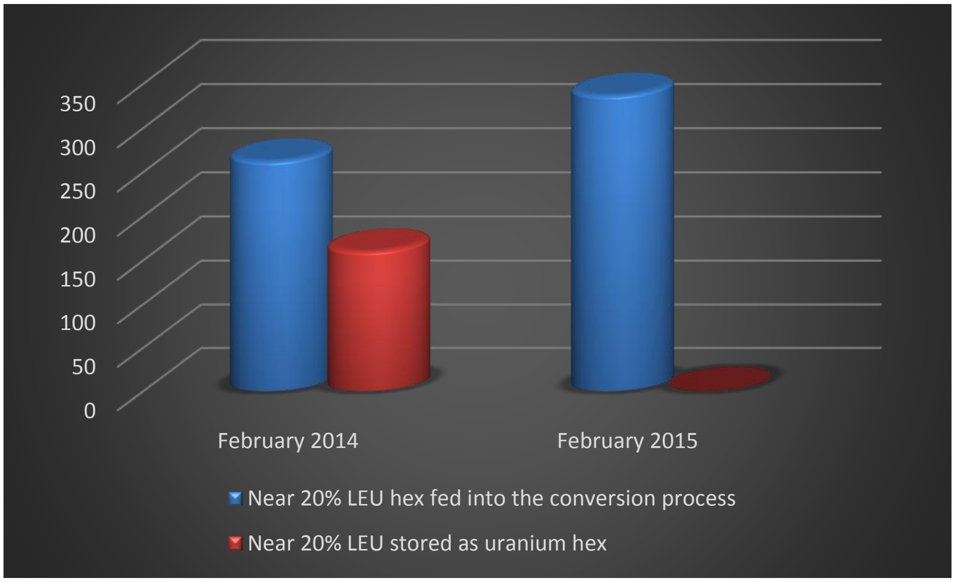
Table 1. February 2015 inventory and fate of UF_6 enriched up to 20 percent LEU (hexafluoride mass)

Total produced at FFEP and PFEP (all UF_6 mass)	447.8 kg
Fed into conversion process at Esfahan	337.2 kg
Downblended	110 kg **
Under IAEA seal, reference material	0.6 kg
In samples taken by the IAEA	0.1 kg
Stored as uranium hexafluoride (UF_6)	0.0 kg

** Includes 1.6 kg downblended previously

Source: IAEA Director General, *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran,* GOV/2015/15, February 19, 2015.

Figure 1. Feeding of near 20 Percent LEU hexafluoride into the Conversion Process, at the beginning of the Interim Period, namely February 2014, and February 2015 (kilograms LEU hexafluoride).



Note: This figure demonstrates that while one chemical form of the near 20 percent enriched uranium (uranium hexafluoride) was eliminated, the other (uranium oxide) increased. Source: IAEA Director General, *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran,* GOV/2015/15, February 19, 2015.

Production of near 20 Percent LEU Oxide Powder, Scrap, and Waste

Overall, Iran has fed 337.2 kilograms of near 20 percent LEU hexafluoride into the conversion process at Esfahan. It is convenient to consider only the mass of the uranium contained in this material, which is 227.6 kilograms. In the remainder of this report, all values given – unless otherwise stated – represent the uranium mass.

The conversion process resulted in the production of 162.3 kilograms in oxide powder form. In its November 2014 report, the IAEA reported that an additional 0.5 kilograms were produced from the material which had previously been in the conversion process. This brings the total to 162.8 kilograms. As of February 2015, a total of 55.4 kilograms were contained in scrap, and about 9.4 kilograms remained in process and in waste, for a total of 64.8 kilograms.

LEU contained in scrap and in-process material can be reused after recovery. Scrap material has significant value and Iran would be expected to seek to recover much of it for conversion into usable uranium oxide (see below).

Production of Fuel Assemblies for the Tehran Research Reactor

As of February 2015, Iran had used 90.6 kilograms of LEU oxide to manufacture fuel assemblies for the TRR, bringing its near 20 percent LEU oxide powder stock down to 72.1 kilograms. This transformation offers advantages to slow potential breakout times. When in fuel assemblies, the LEU is in a less re-convertible form. However, putting the LEU into TRR fuel does not eliminate the threat posed by this material. Although such a step complicates its recovery and use in centrifuges during a breakout, the LEU can be recovered from the fresh fuel in significantly less than a year.[1]

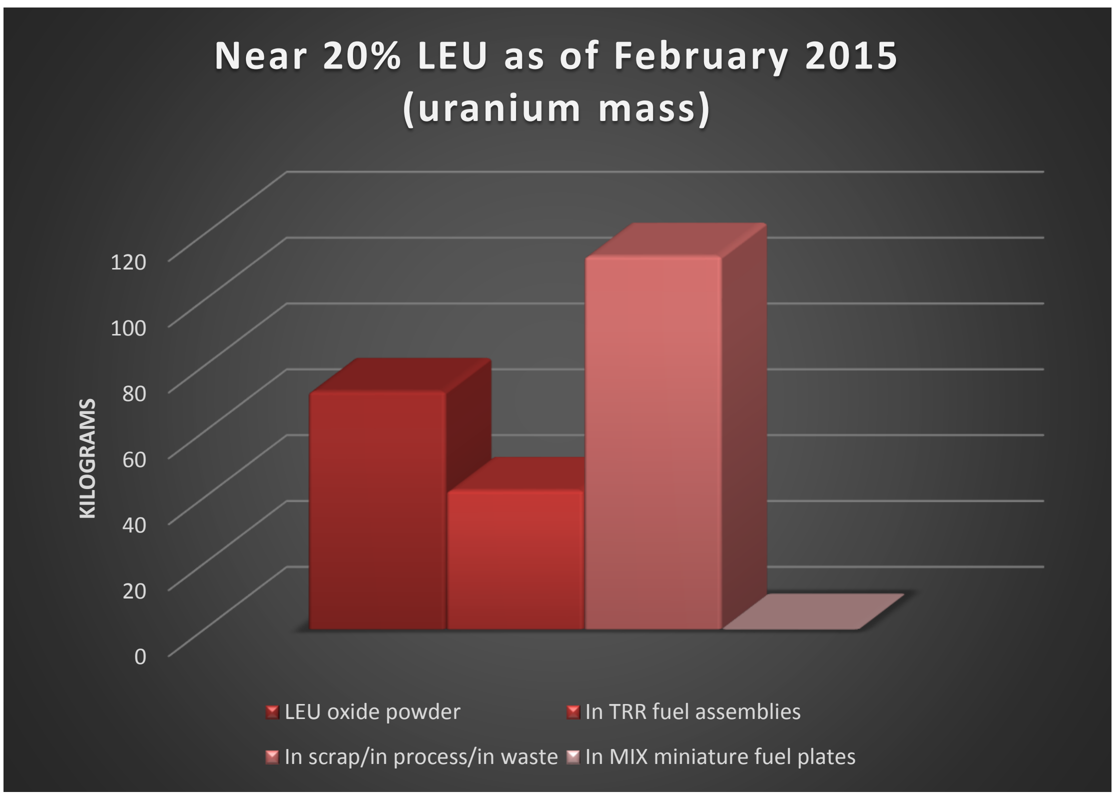
Using the 90.6 kilograms, Iran manufactured five TRR test plates (75 grams each), nine control fuel rods (1,000 grams each), 23 standard fuel assemblies (1,400 grams each), and one test assembly (550 grams), for a total of 42.1 kilograms. Only 46.5 percent of the LEU ended up in fuel elements.

The fate of the 48.5 kilograms not in the fuel is not discussed in detail in the IAEA report. Nonetheless, the report states that it is in process lines, scrap, waste, and in storage tanks linked to the manufacturing process.

Adding the 64.8 kilograms of scrap and waste generated during the conversion of near 20 percent LEU hexafluoride into oxide powder, the total amount in scrap, process lines, and waste was about 113.3 kilograms, as of February 2015. Thus, a relatively large fraction remains in scrap and waste.

Figure 2 shows graphically the results as of February 2015. As can be seen, about half of the LEU was in the form or scrap, waste, or in-process at this time.

Figure 2. Near 20 percent LEU oxide as of February 19, 2015 (in kilograms, uranium mass).



Source: IAEA Director General, *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran,* GOV/2015/15, February 19, 2015.

[1] See David Albright, Andrea Stricker, Serena Kelleher-Vergantini, and Houston Wood, "P5+1/Iran Framework: Needs Strengthening," ISIS Report, April 11, 2015, http://www.isis-online.org/uploads/isis-reports/documents/Assessment_of_Iran_Nuclear_Framework_April_11_2015-final.pdf.

Extension Agreements: Highly Inefficient Use of LEU

Under the first extension of the Joint Plan of Action (JPA), signed in July 2014, Iran committed to manufacturing 25 kilograms of LEU oxide into fuel assemblies for the Tehran Research Reactor. Although a straightforward reading of this pledge might have suggested that those 25 kilograms would be the amount ending up in the fuel assemblies, they did not. For example, only about 5.2 kilograms did so as of October 2014 out of the 17 kilograms used to make the fuel assemblies, a rate of only about 30 percent, far below the average value of about 46 percent derived above.[2] The rest is in scrap, in process lines, or in waste.

The resumption in the production of TRR fuel assemblies did not actually start until at least August instead of July 2014. (See figure 3 which shows that between May 2014 and August 2014, the amount of near 20 percent LEU in fuel assemblies remained unchanged.) Thus, Iran appears to have tried to process a relatively large amount of LEU oxide in two to three months, or about 8-12 kg per month, possibly helping explain the greater than expected inefficiency of using the LEU.

Under the second extension, signed in November 2014, Iran committed to use another 35 kilograms of LEU oxide to make TRR fuel assemblies by June 2015, or an average of about 5 kg per month. However, from the middle of October 2014 until the middle of February 2015, Iran fed into the process only an additional 6 kilograms of LEU. It did manage to get 2.8 kilograms into the fuel assemblies, a rate of about 47 percent. A fraction of this LEU was processed in the first extension period, however.

So far, in this second extension, Iran has not yet achieved an average of 5 kg of LEU per month. According to the April IAEA Iran Joint Plan of Action report, Iran used 40.2 kg of near 20 percent LEU for the manufacture of TRR fuel between July 2014 (date of the first extension and pledge to use LEU for TRR fuel) and mid-April 2015[3]. The report did not report on the amount that actually ended up in TRR fuel. Based on this value, Iran needs to process another 20 kilograms of near 20 percent LEU oxide into TRR fuel in two and a half months, at an average rate of about 8 kg per month.

Based on this track record, the amount of near 20% LEU oxide that will end up in fuel by June 2015 will not be, in fact, 35 kilograms, but a significantly smaller amount, perhaps as little as 10-18 kilograms, based on the conversion rates achieved so far.

Scrap Recovery

According to the February 2015 IAEA report, Iran stated that it intends to recover the near 20 percent LEU from scrap at the FPFP. According to the IAEA report, "In a letter dated 28 December 2014, Iran informed the Agency [IAEA] of the operational schedule for FPFP [Fuel Plate Fabrication Plant at Esfahan] and indicated its intention to establish process lines for the recovery of uranium from solid and liquid scrap. In its reply dated 19 January 2015, the Agency requested that Iran provide further clarification. On 10 February 2015, the Agency observed that the process lines had yet to commence operation and that Iran had started R&D activities related to the recovery of uranium from solid scrap."

It is unknown how much near 20 percent LEU scrap would be recovered, or whether the scrap sent for processing would be covered explicitly by the extension agreements and a comprehensive agreement.

[2] The fraction in fuel assemblies is 5.2 divided by 17.1, or 30 percent.

[3] IAEA Director General, *Status of Iran's Nuclear Program in relation to the Joint Plan of Action,* April 20, 2015, http://isis-online.org/uploads/isis-reports/documents/IAEA_JPA_update_20Apr2015.pdf.

However, Iran moving to institute a scrap recovery capability poses a challenge to the negotiations, since the recovered LEU would be easier to use in breakout.

Target Production and Separation Operations

In addition to making TRR fuel, on December 28, 2014 Iran notified the IAEA that it would start manufacturing miniature fuel plates for the Molybdenum, Iodine and Xenon Radioisotope Production (MIX) Facility, for the production of Molybdenum-99 in the TRR. As of February 9, the IAEA confirmed that one fuel plate containing a mixture of U_3O_8 enriched up to 20 percent uranium-235 and aluminum were at the MIX Facility after transfer from the FPFP and was being used for R&D activities for the production of ^{99}Mo, ^{133}Xe, and ^{132}I isotopes. According to the IAEA reports, since July 24, 2014, Iran has used 0.084 kg of near 20 percent uranium oxide for the purpose of producing ^{99}Mo. As can be seen, the amounts of LEU used to make targets so far are very small.

However, the processing of such targets after irradiation in the TRR can also provide experience in developing a capability to recover the LEU. Although the targets are processed to recover key isotopes, the processing provides experience in separating LEU from the aluminum in fresh fuel. In fact, unless prohibited, Iran could establish a scrap recovery capability to recover the LEU from defective fresh targets so as to reuse the LEU.

Projected Near 20 Percent LEU Stock at End June 2015 and Its Ramifications

The available information allows a projection of the near 20 percent LEU stocks as of the end of this most recent extension, or the end June 2015 (see table 2). This date could also coincide with the signing of a long-term deal. Addressing the fate of these stocks of LEU so as to preserve a 12 month breakout estimate will be a challenge for negotiators.

In total, at the end of June, Iran will possess about 228 kg of near 20 percent LEU (uranium mass). By this date, Iran is expected to have used approximately 119.6 kilograms of LEU oxide powder to make TRR fuel assemblies, leaving about 43.1 kg as fresh oxide powder. Applying the highest efficiency rate of the overall process discussed here, slightly above 50 percent, from November 2014 to June 2015, an additional 18 kilograms of this LEU would end up in fuel assemblies, bringing the cumulative amount to about 60 kilograms. The cumulative fuel manufacturing process is expected to yield a total of about 60 kilograms of material in scrap, in process and in waste. Adding the 65 kilograms of scrap and waste generated during the conversion of near 20 percent LEU hexafluoride into oxide powder, the total amount in scrap, process lines, and waste would be about 125 kilograms.

Table 2. Production and fate of near 20 percent LEU oxide in Iran (in kilograms, rounded to one decimal place)

Overall Near 20% LEU Stocks and Forms						
Date	LEU in Oxide Powder, Cumulative (kg U-mass)	LEU Used for TRR Fuel (kg U-mass)			LEU in Scrap, Process, Waste, Cumulative (kg U-mass)[b]	Total LEU Kg U-mass
		Cumulative	In TRR Fuel[a]	Scrap/process/waste		
July 20, 2014	103.5	59.3[c]	Not Available	Not Available	64.8	227.6
Aug. 17, 2014	97.6	65.2	34.1	31.1	95.9	227.6
Oct. 17, 2014	86.4	76.4	39.3	37.1	101.9	227.6
Feb. 19, 2015	72.1	90.7	42.1	48.5	113.3	227.6
Mid-April 2015	63.3	99.5	Not Available	Not Available		227.6
Projected Status, end of June 2015	43.1	119.7[d]	59.8[e]	59.8[e]	124.6	227.6

Comments

a) See IAEA quarterly reports on the *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran.*

b) This column accounts for the scrap, process, and waste generated from the conversion to oxide process and from the fuel fabrication process.

c) This number was derived from information provided by the IAEA in quarterly and JPA compliance reports.

d) Amount used as of November 24, 2014, plus the 35 kg stipulated for fuel manufacturing under the November 2014 extension of the JPA.

e) Estimate, based on the highest, overall, efficiency rates, or 39.3 kg divided by 76.4 kg which equals 51.4 percent applied to the 35 kg of LEU to be used in the second extension that runs from late November 2014 through June 2015.

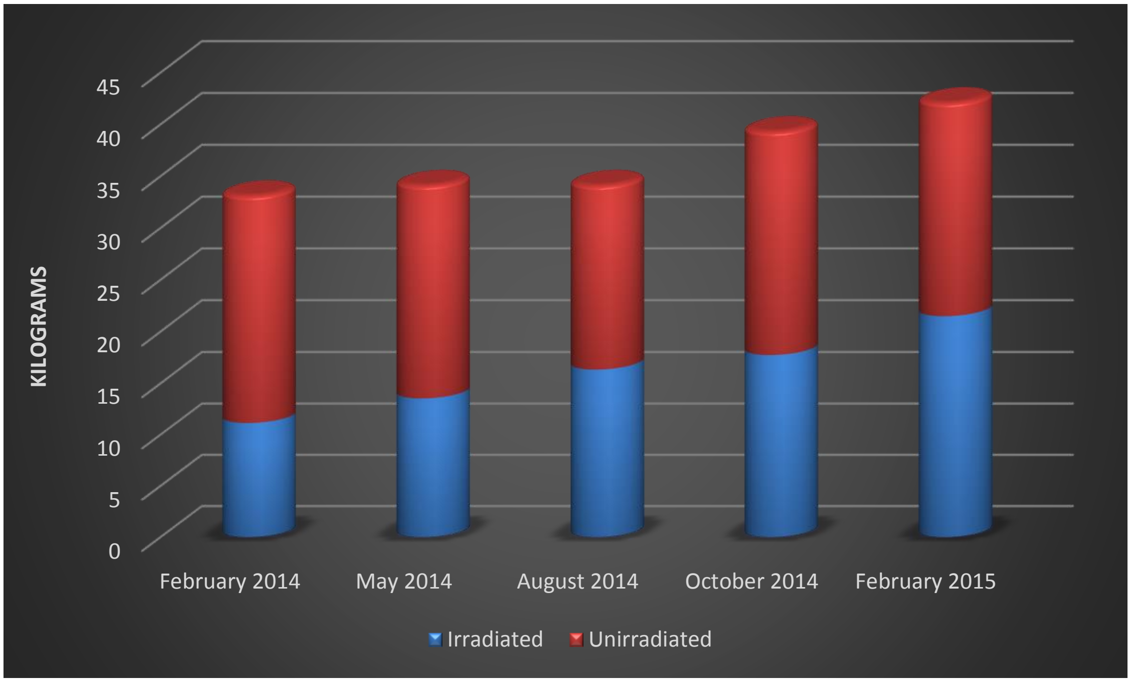
Because this LEU can be recovered in a straightforward manner from a uranium/aluminum mixture in fuel or in a production form, the amount of near 20 percent LEU should be reduced as much as possible. For example, if Iran can produce 50 kilograms near 20 percent LEU hexafluoride (about 36 kilograms uranium mass) or about 16 percent of its total stock in four to six months, it can reduce a 12 month breakout timeline to about eight months.

Thus, a challenge for negotiators is to remove from Iran or blend down to natural uranium most of this LEU. The obvious target is the expected 43 kg in oxide powder and the 125 kg in the form of scrap, waste, and in-process. These amounts total to 168 kg and represent almost 75 percent of Iran's stock of near 20 percent LEU. However, leaving LEU in fresh TRR fuel could also undermine a 12-month breakout estimate.

One simple way to significantly reduce the breakout risk posed by the fresh near 20 percent LEU in fuel is to irradiate it in the TRR. Once irradiated, the LEU fuel poses a radiation risk and would need to be separated in heavily-shielded facilities, a significantly more difficult and time consuming process compared to recovering LEU from fresh fuel.

However, Iran has irradiated only about half of its new TRR fuel. As of February 2015, Iran had irradiated only two test plates (75 grams each), six control fuel assemblies (1,000 grams each) and eleven standard fuel assemblies (1,400 grams each) – 21.5 kilograms in total (see figure 3). Thus, up to 40 kg of LEU (uranium mass) could be in fresh TRR fuel at the end of June. This amount is equivalent to about 60 kilograms LEU hexafluoride if recovered and reconverted into hexafluoride form.

Figure 3. Amounts of near 20 percent LEU (uranium mass) in kilograms contained in fuel assemblies for the Tehran Research Reactor.



Source: IAEA Director General, Quarterly Reports on the *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran,* February 2014 – February 2015.

The Irradiation rate in the TRR could remain relatively low. Over the next several years, the TRR, which is a small reactor, is expected under normal operation to irradiate less than the equivalent of tens of kilograms of near 20 percent LEU hexafluoride. Thus, much of the TRR fuel could be expected to remain fresh for many years.

One possible compromise in a comprehensive solution would be for Iran to irradiate for many months all of its fresh TRR fuel sequentially during the first year or two of a comprehensive solution. The partially irradiated fuel could then be stored in the spent fuel pond until it was needed to replace fully irradiated fuel.